Bangladesh J. Agri. 2012, 37(1): 91-99

EFFECTS OF NITROGEN AND BORON ON THE YIELD AND HOLLOW STEM DISORDER OF BROCCOLI

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Abstract

A field experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during winter season 2003-2004 to determine the role of N and B on the yield and hollow stem disorder of broccoli and to determine the optimum dose of N and B for broccoli production as well as to control hollow stem disorder. The experiment was conducted with four levels of N as 0, 60,120, 180 kg ha^{-1} and four levels of B as 0, 0,5, 1.0 and 1.5 kg ha^{-1} as treatment variables. Applied N and B had significant impact on the yield and hollow stem disorder of broccoli. The highest curd yield (15.14 t ha^{-1}) was found with the maximum rate of N (180 kg ha-1) and the incidence of hollow stem disorder was increased by increasing rate of N application attaining the highest value of hollow stem index (1.39) with 180 kg N ha^{-1}. The curd yield of broccoli was increased with the boron application up to 1.0 kg ha^{-1} and showed a remarkable impact on reduction of hollow stem disorder. A moderately high amount of B application (1.0 kg ha^{-1} has led to the minimum incidence of hollow stem disorder attaining considerably lowest value of hollow stem index of 1.00 as against the maximum value of 1.16 under no application of B. The interaction effect of N and B on yield and quality of broccoli was significant and the highest curd yield (16.68 t ha-1) was recorded under 180 kg N and 1.0 kg B ha^{-1}, which may be considered to be the optimum doses for achieving satisfactory yield and controlling hollow stem disorder of broccoli in Shallow-Red-Brown Terrace Soil of Madhupur Tract.

Introduction

Broccoli (*Brassica oleracea* var. *Italica L. Cymosa Lam.*) is an important vitamin rich winter vegetable. It is a member of Cole crops belongs to the family Cruciferae. It is fairly rich in carotene and ascorbic acid and contains appreciable quantities of thiamin, riboflavin, niacin and iron (Thompson and Kelly, 1985). Successful production of broccoli depends on various factors of which fertilizer application is the most important one. Hollow stem disorder is a major problem to broccoli production which is responsible to yield reduction is commonly associated with B deficiency (Shelp *et al.,* 1992) as well as higher nitrogen rates (Babik and Elkner, 1999). More N application to soil resulted in decreased take up of B by the crops (Kotur, 1997). The incidence of hollow stem is increased by increasing application of nitrogen fertilizer (Cutcliffe, 1972; Hipp, 1974). Boron deficiency causes many anatomical, physiological and biochemical changes. It was reported by Lent and Scarchuk (1954) that stem hollowing in the brassicas has long been associated with B deficiency. According to Bradford (1975), boron deficiency is associated with hollow stem disorder in cauliflower, where nitrogen application at higher rates is known to aggravate the problem. Broccoli cultivar Premium Crop

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is a susceptible variety to boron deficiency as well as hollow stem disorder (Shattuck and Shelp (1987)). Therefore, nitrogen and boron management is a crucial factor for yield and quality as well as to control hollow stem disorder of broccoli. So, the study was undertaken to determine the role of N and B on yield and hollow stem disorder of broccoli and to determine the optimum doses of N and B for broccoli production as well as to control hollow stem disorder.

Materials and Methods

The experiment was conducted at the research farm of Bangabandhu Sheikh Muzibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh, during November 17, 2003 to February 13, 2004. The soil of the experimental site was silty clay loam in texture having the bulk density 1.40 g cm^{-3} which belongs to Salna series of Shallow Red-Brown Terrace Soil under Agro-Ecological Zone Madhupur Tract (AEZ 28). Some chemical properties of the soil are presented in Table 1.

Table 1. Some chemical properties of the soil of experimental site

Chemical properties	Analytical results	Critical values
Soil pH	6.4	-
Total N (%)	0.11	0.12
Organic carbon (%)	1.146	C:N= 10:1
C:N ratio	10.42	10:1
Boron (µg/g soil)	0.455	0.2
Available P (µg/g soil)	25.583	10.0
Exchangeable K (meq/100g soil)	0.363	0.12
Available S ((µ g/g soil))	44.32	10.0
Total Zn (µg/g soil)	3.25	0.6
Exchangeable Ca (meq/100g soil)	7.448	2.0
Exchangeable Mg (meq/100g soil)	2.21	0.5
CEC (meq/100g soil)	11.908	-

The Experiment was carried out in a split-plot design with three replications. Four levels of nitrogen 0, 60, 120 and 180 kg N ha^{-1} were assigned in the main plots and four levels of boron 0, 0.5, 1.0 and 1.5 kg B ha^{-1}in sub-plots. The row to row and plant to plant distance was 60 and 45 cm, respectively. All other fertilizers were applied uniformly as a blanket dose for all treatment at the rate of 53P:83K:20S:2Zn: 0.8 Mo kg ha^{-1}. Twenty five day-old healthy seedlings of broccoli (var. Italica L. cv. Premium Crop) were transplanted in the experimental plot on 17 November, 2003. All the fertilizers except urea and MoP were applied as basal and were incorporated into the soil during final land preparation. Urea and MoP were applied in two equal splits at 15 and 30 DAT followed by ring method around the plant bases. At an early stage, sprinkler irrigation was applied and at later stages irrigation water was applied in the furrows at an interval of 7 days. Necessary intercultural operations and weeding were done properly. Crop harvesting was started on 17th January and continued up to 28th January.

Data on different plant parameters were recorded from 10 randomly selected plants located at the middle of each plot leaving adequate border plants. Similar number of plants and curds were observed for determination of yield and hollow stem disorder. The crop was harvested when the curd/inflorescence attained at commercial maturity (13-15 cm in diameter and just started to swell but before opening the flower bud). The weight of individual curd was taken including the stalk with three young leaves and the marketable portion of the plant was considered to the extent of about 15 cm from the top of the inflorescence along the stem (Liu *et al.*, 1993). Hollow stem index (HI) was determined by the methodology followed by Shattuck and Shelp (1987) and was rated through visual inspection of longitudinal section of the stalk

and head. Accordingly, the incidence of hollow stem was observed at the stem base of heads, 15-18 cm in length according to Shattuck *et al.* (1986) and was expressed as hollow stem index (HI) as stated by Shattuck and Shelp (1987). Each longitudinal head section was scored according to the scale: 0 = hollow stem absent, 1 = slight hollow stem, 2 = moderate hollow stem and 3 = severe hollow stem.

The hollow stem index (HI) for each replication was calculated using the following equation:

$$HI = \sum_{i=0}^{3} n_i X_i / N$$

Where,
n_i = number of plants in the ith scale class
X_i = the ith scale value and
N = total number of plants scored.

The highest index indicates the most severe case of hollow stem disorder and the lowest indicates the least hollow stem disorder. Data were analyzed statistically by using a computer program "MSTATC". The values of hollow stem index were converted to a degree by squire root transformation prior to analysis to bring homogeneity and additivity. The treatment comparison was made followed by Duncan's Multiple Range Test (DMRT) at 5% level of probability. Correlation co-efficient and regression analysis were done using Microsoft Excel program.

Results and Discussion

Effect of N on different plant parameters, curd yield and hollow stem index

Plant height

A significant effect of N was found on plant height. It was increased with the increasing rate of N application and the highest plant height (70.68 cm) was recorded with 180 kg N ha^{-1} and it was significantly different from all other treatments (Table 2). Minimum plant height was found from the treatment without N fertilizer. Nitrogen application at the rate of 60, 120 and 180 kg ha^{-1} in presence of other elements showed 20.6, 23.3 and 28.6% higher plant height over control. Higher amount of nitrogen application had led to better vegetative growth of plants to attain the highest plant height. This result was supported by Letey *et al.* (1983).

Stem diameter

The diameter of the stem varied significantly with different levels of N fertilizer. It was increased with the increasing rate of N upto 180 kg ha^{-1} (Table 2) and the maximum diameter (5.83 cm) was recorded from 180 kg N ha^{-1} which was statistically similar to 120 kg N ha^{-1}. Minimum stem diameter (3.90 cm) was found from the treatment without N fertilizer.

Curd diameter

The shape of the main curd is a genetic character. The cultivar used in the experiment had round head. The curd diameter in this cultivar can be considered as an appropriate measure of curd size. The curd diameter was increased significantly with increasing rate of N fertilizer (Table 2). The highest dose of N (180 kg ha^{-1}) produced the maximum curd diameter (15.02 cm) which was statistically similar to those obtained from the levels 120 and 60 kg N ha^{-1}. The lowest curd diameter (9.15 cm) was recorded from the plot where N was not applied. The

increment of curd diameter was 64.15 and 54.64% under application of 180 and 120 kg N ha^{-1}, respectively as compared to 0 kg N ha^{-1}. This result is very close to the findings of Thompson and Kelly (1985).

Curd yield

There was a significant response of curd yield (t ha^{-1}) of broccoli to different levels of N fertilizer. Curd yield increased significantly with the incremental doses of N application (Table 2). The highest yield of 15.14 t ha^{-1} was recorded under the highest rate of N application (180 kg ha^{-1}) which was significantly different from all other treatments. The rate of increased curd yield of broccoli by application of 180, 120 and 60 kg N ha^{-1} over the control treatment (0.0 kg N) were 254.57, 171.66 and 59.25 %, respectively, thus signifying the indispensability of higher doses of N application for achieving better yield of broccoli.

Hollow stem index (HI)

The hollow stem index (HI) recorded from the experiment was significantly influenced by the different levels of N (Table 2). It was revealed that the hollow stem index of broccoli was favored by increasing rate of N application and the maximum severity of hollow stem disorder (HI-1.389) was noted under the application of highest dose of N (180 kg N ha^{-1}) which was significantly higher than those of any other treatments. The intensity of this disorder decreased significantly with decrease in N rate and was attained to the minimum value of 0.742 with no application of N. It was found from the observation that increased rate of N application have increased the vegetative growth of plants and the turgidity of plant cells that might have led to hollowness in the stem.

Effect of B on different plant parameters, curd yield and hollow stem index

Plant height

The effect of B on plant height was also found significant (Table 2). In that case, plant height was significantly influenced by the different levels of B and it was gradually increased up to the rate 1.0 kg B ha^{-1} and then decreased. The maximum plant height (65.72 cm) was noted from the treatment receiving B at the rate of 1.0 kg ha^{-1} which was statistically similar to 0.5 and 1.5 kg B ha^{-1}. The minimum plant height (63.50 cm) was found from the treatment without B. Sharma and Arora (1984) reported the maximum plant height from 2.5 kg B ha^{-1} in cauliflower which relates this findings.

Stem diameter

Stem diameter was increased with increasing rate of B up to 1.0 kg ha^{-1} and then decreased (Table 2). The higher dose of B (1.0 kg ha^{-1}) produced the maximum stem diameter (5.32 cm) which was statistically similar to 1.5 and 0.5 kg B ha^{-1}. The lowest stem diameter (4.70 cm) was recorded from the treatment without B. Application of higher levels of B led to an increase in stem diameter of broccoli but it was increased up to a certain limit and then declined.

Curd diameter

Curd diameter was significantly increased by B application but there was no significant variation among B added plots (Table 2). The maximum curd diameter (13.32 cm) was recorded under application of 1.5 kg B ha^{-1} followed by 1.0 kg B ha^{-1} which produced a curd diameter of

13.31 cm. The minimum diameter was found in treatment where no B was added. This result was related to Sanjoy *et al.* (2002) as they opined that Mo and B application significantly increased the curd diameter, weight and yield of cauliflower.

Curd yield

Curd yield was also significantly increased by adding B to soil up to 1.5 kg ha^{-1} (Table 2). Higher curd yield (10.25 t ha^{-1}) was obtained from1.5B kg ha^{-1}, which was statistically similar to 1B kg ha^{-1} (10.15 t ha^{-1}). The minimum yield (8.23 t ha^{-1}) was recorded from the B level 0 kg ha^{-1}. Boron application at the rate of 1.5, 1.0 and 0.5 kg gave 24.54, 23.37 and 11.54 % higher curd yield, respectively over control.

Hollow stem index (III)

Hollow stem index was also significantly influenced by different B level. It was decreased with the increase in B level up to 1.0 kg ha^{-1} and then increased (Table 2). The highest hollow stem index (1.161) was found from the B level 0 kg ha^{-1}, which was significantly different from all other B levels. The minimum hollow stem index (1.003) was noted from 1B kg ha^{-1}. It means that increase of B level up to a certain limit may decrease the hollow stem disorder.

Table 2. Effect of N and B on different plant parameters, curd yield and hollow stem index of broccoli

Treatment	Plant height at maturity (cm)	Stem diameter (cm)	Curd diameter (cm)	Curd yield (t/ha)	Hollow stem index (HI)
N level (kg ha^{-1})					
0	54.95 c	3.90 c	9.146 c	4.270 d	0.742d
60	66.25 b	4.96 b	12.76 b	6.802 c	0.930c
120	67.78 b	5.74 a	14.15 ab	11.601b	1.261b
180	70.68 a	5.83 a	15.02 a	15.140 a	1.389a
SE (±)	0.79	0.14	0.56	0.20	0.03
CV (%)	2.77	6.44	6.29	5.67	6.49
B level (kg ha^{-1})					
0	63.50 b	4.70 b	11.76 b	8.230 c	1.161a
0.5	64.95 ab	5.14 a	12.70 a	9.180 b	1.076b
1.0	65.72 a	5.32 a	13.31 a	10.153 a	1.003c
1.5	65.50 a	5.27 a	13.32 a	10.247 a	1.081b
SE (±)	0.53	0.10	0.23	0.16	0.02
CV (%)	2.77	6.44	6.29	5.67	6.49

Results followed by the common letters are not significantly different from each other at 5% level of significance by DMRT

Interaction between N and B on different plant parameters, curd yield and hollow stem index

The interaction effects of N and B on plant height, stem diameter and curd diameter of broccoli was found insignificant. But curd yield of broccoli was significantly influenced by the combined effect of N and B application (Table 3). It was revealed that curd yield was increased with the increasing rate of N application but it was increased with B up to 1.0 kg B ha^{-1} and then decreased with further incremental rate of B application. The highest curd yield (16.68 t ha^{-1}) was obtained from the combined dose of 180 N: 1B kg ha^{-1} which was significantly different from all other treatment combinations. Mishra and Singh (1984) found the similar interaction effect on this character in cauliflower. This might be due to the higher crop growth with high accumulation and translocation of photosynthetic materials to the curd. From above discussion, it may be ascertained that the combined dose of N and B application at the rate of 180 kg N

along with 1.0 kg B ha^{-1} are the optimum dose to be applied to soil for getting maximum yield of broccoli.

Similarly a significant interaction effect of N and B was found on the hollow stem index (HI) of broccoli (Table 3). The maximum hollow stem index (1.549) was recorded from the combination of 180 N: 0 B kg followed by 180 N: 1.5 B kg, and 120 N: 0 B kg which were statistically similar to each other and the minimum HI (0.707) was found from the combination of 0N: 0 B kg. It was revealed that increasing rate of N also increased the hollow stem index under each B level. It was observed that within N level 180 kg ha^{-1}, hollow stem index decreased up to 1.0 kg B level and then it was increased. The intensity of this disorder decreased significantly with decrease in N rate and was attained to the minimum value of 0.707 with no application of N and B. But, increase in B level up to a certain limit with higher doses of N, decreased the hollow stem disorder. It revealed from the observation that increased rate of N application positively increased the vegetative growth of plants and the turgidity of plant cells that might have led to hollowness in the stem. Both yield and curd quality was affected and reduced due to the presence of hollow stem disorder. But this could be checked by using B at the rate of 1.0 kg ha^{-1} through which curd quality of broccoli was improved.

Table 3. Interaction effect of N and B on curd yield (t ha^{-1}) and hollow stem index of broccoli

Treatment	N level (kg ha^{-1})			
	Curd yield (t ha^{-1})			
B level (kg ha^{-1})	0	60	120	180
0	4.070 j	5.227 i	9.533 f	14.090 bc
0.5	4.300 ij	6.610 h	10.780 e	15.030 b
1.0	4.343 ij	7.153 h	12.440 d	16.680 a
1.5	4.367 ij	8.217 g	13.65 c	14.760 b
SE (±)	0.31			
CV (%)	5.67			
	Hollow stem index (HI)			
B level (kg ha^{-1})	0	60	120	180
0	0.7071f	0.9500 e	1.4370 ab	1.5490 a
0.5	0.7499 f	0.9417 e	1.2610 cd	1.3520 bc
1.0	0.7478 f	0.8911 e	1.1800 d	1.1950 d
1.5	0.7646 f	0.9357 e	1.1660 d	1.4590 ab
SE (±)	0.04			
CV(%)	6.49			

Results followed by the common letters are not significantly different from each other at 5% level of significance by DMRT

Correlation regression analysis results

Curd yield

From the response curve (Fig 1) it was found that the yield was highly correlated with N level showing $R^2 = 0.9876$, which indicated that maximum increase in curd yield by 99 % with the highest N level, 180 kg ha^{-1}. Research findings from the works of Gorski and Armstrong (1985), Default (1988), Kawalenko and Hall (1987), Trimblay (1989) had supported the findings of the study. Erdem *et al.* (2010) also reported that the yield of broccoli (var. Italica) was increased with increasing rate of nitrogen application. Similar results were observed by Moniruzzaman *et al.* (2007) for broccoli. It was found that the yield was highly correlated with B level depicting $R^2 = 0.9168$, which indicated that maximum increase in curd yield by 92% with the highest B level 1.5 kg ha^{-1}(Fig 2). These findings are in agreement with the results of Singh *et al.* (2002) for cauliflower with application of B up to1.0 kg ha^{-1}.

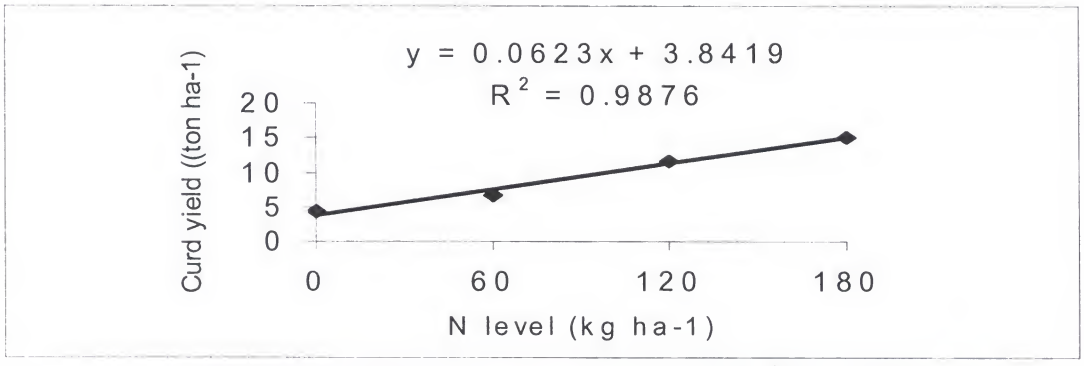

Fig. 1. Effect of different nitrogen levels on curd yield (t ha^{-1} of broccoli)

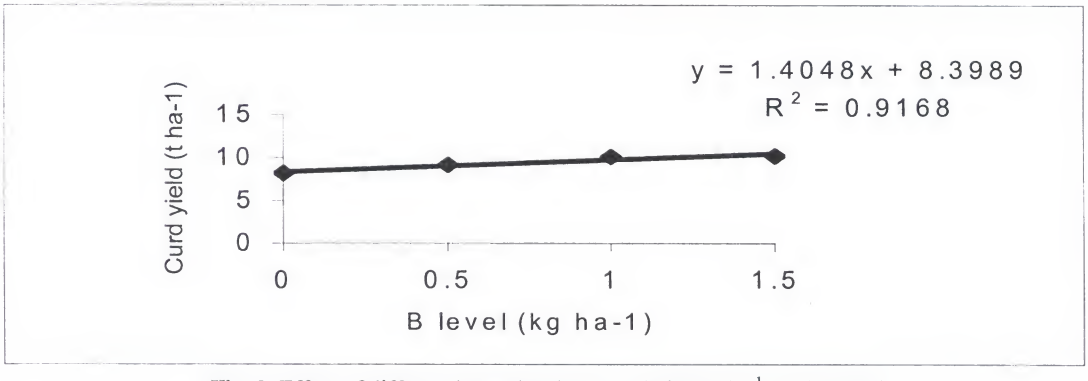

Fig. 2. Effect of different boron levels on curd yield (t ha^{-1}) of broccoli

Hollow stem index

From the response curve it was also found that the HI was highly correlated with N level and having the value of $R^2 = 0.9739$ (Fig. 3), which indicated that maximum increase in HI by 97% with the highest N level of 180 kg ha^{-1}. This result was supported by the findings of Gorski and Armstrong (1985) as stated that hollow stem in broccoli is intensified by rapid maturation and increasing N rate. It was also observed from the response curve that the HI negatively correlated with B levels having $R^2 = 0.9228$ (Fig. 4), which indicated that maximum decrease in HI by 92% with the highest B level of 1.0 kg ha^{-1}. This result supported the findings of Lent and Scarchuk (1954) mentioning that stem hollowing in the brassicas has long been associated with B deficiency. It also related to the findings of Vigier and Cutcliffe (1984) as found that a portion of the hollow stem disorder in broccoli could be attributed to B deficiency. The findings also supported by Shattuck and Shelp (1987) where they found that broccoli variety Premium Crop grown in the absence of B showed initial signs of hollow stem which was alleviated by adding B and suggested B nutrition as involved in the induction of hollow stem in broccoli. Similarly, Moniruzzaman *et al.* (2007) reported that B deficiency is associated with hollow stem disorder in broccoli.

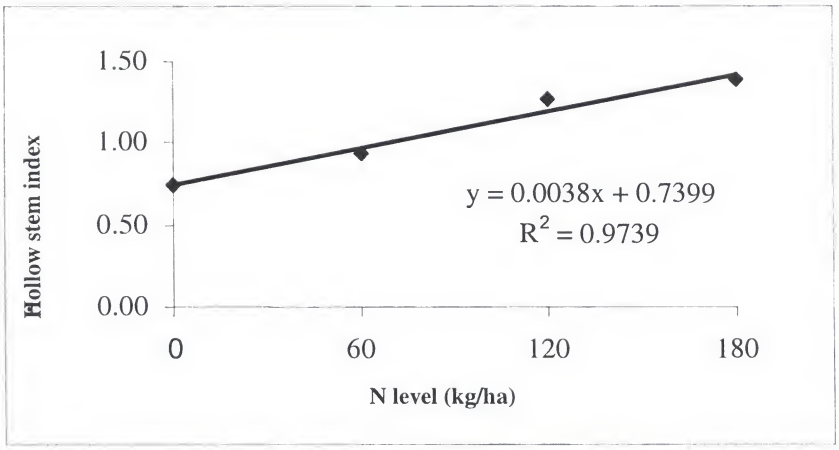

Fig. 3. Effect of different levels of N on hollow stem index of broccoli

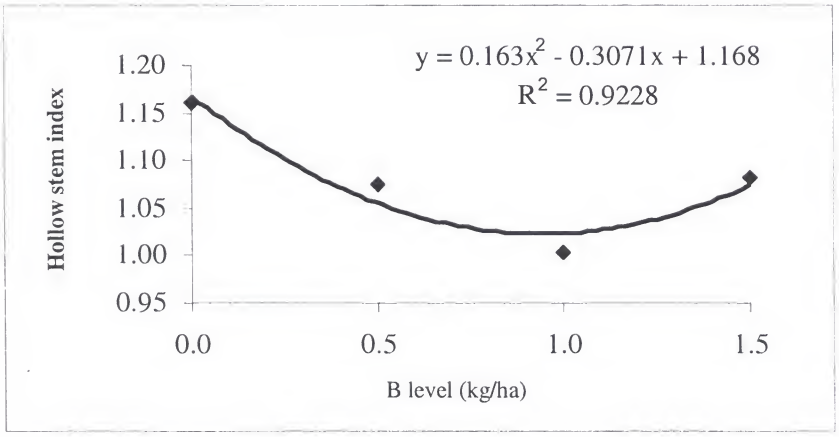

Fig. 4. Regression analysis of different levels of B on hollow stem index of broccOli

Conclusion

Based on the results of the study it could be concluded that hollow stem disorder in broccoli is favored by higher rate of N application, while B application up to 1.0 kg ha^{-1} would reduce the incidence of hollow stem without hampering the crop yield. Considering the yield and quality of broccoli, a combined application of 180 kg N with 1.0 kg B ha^{-1} has been found suitable for achieving higher yield of quality broccoli. Therefore, the combined dose of 180 kg N and 1.0 kg B/ha could be considered for achieving the maximum yield of broccoli in Shallow-Red-Brown Terrace Soil of Madhupur Tract.

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